VERMONT YANKEE
NUCLEAR POWER CORPORATION

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Dec. 23, 1997
BVY 97-178

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington D.C. 20555

Reference: (a) License No. DPR-28 (Docket No. 50-271)

Subject: Reportable Occurrence No. LER 97-023, Rev. 0

As defined by 10CFR50.73, we are reporting the attached Reportable Occurrence as LER 97-023, Rev. 0.

Sincerely,

VERMONT YANKEE CORPORATION

Gregory A. Maret
Plant Manager

cc: USNRC Region I Administrator
USNRC Resident Inspector – VYNPS
USNRC Project Manager – VYNPS

CATEGORY 1

REGULATORY INFORMATION DISTRIBUTION SYSTEM (RIDS)

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AUTH.NAME AUTHOR AFFILIATION
MARET,G.A. Vermont Yankee Nuclear Power Corp.
RECIP.NAME RECIPIENT AFFILIATION

SUBJECT: LER 97-023-00:on 971125,reactor scram was noted.Caused by component failure in main generator protection circuitry. Craft & engineering personnel performed troubleshooting of affected main generator protection circuitry.W/971223 ltr.

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NRC Form 366 (4-95) U.S. NUCLEAR REGULATORY COMMISSION LICENSEE EVENT REPORT (LER)	APPROVED BY OMB NO. 3150-0104 EXPIRES 04/30/98 ESTIMATED BURDEN PER RESPONSE TO COMPLY WITH THIS MANDATORY INFORMATION COLLECTION REQUEST: 50.0 HRS. REPORTED LESSONS LEARNED ARE INCORPORATED INTO THE LICENSING PROCESS AND FED BACK TO INDUSTRY. FORWARD COMMENTS REGARDING BURDEN ESTIMATE TO THE INFORMATION AND RECORDS MANAGEMENT BRANCH (T-6 F33), U.S. NUCLEAR REGULATORY COMMISSION, WASHINGTON, DC 20555-0001, AND TO THE PAPERWORK REDUCTION PROJECT (3150-0104), OFFICE OF MANAGEMENT AND BUDGET, WASHINGTON, DC 20503.

FACILITY NAME (1)	DOCKET NUMBER (2)	PAGE (3)
VERMONT YANKEE NUCLEAR POWER STATION	05000271	01 OF 08

TITLE (4) A COMPONENT FAILURE IN THE MAIN GENERATOR PROTECTION CIRCUITRY RESULTS IN A REACTOR SCRAM

EVENT DATE (5)			LER NUMBER (6)			REPORT DATE (7)			OTHER FACILITIES INVOLVED (8)	
MONTH	DAY	YEAR	YEAR	SEQUENTIAL NUMBER	REVISION NUMBER	MONTH	DAY	YEAR	FACILITY NAME	DOCKET NO.(S) 05000
11	25	97	97	-- 023 --	00	12	23	97	N/A	

OPERATING MODE (9)	N
POWER LEVEL (10)	85

THIS REPORT IS SUBMITTED PURSUANT TO THE REQUIREMENTS OF 10 CFR §: CHECK ONE OR MORE (11)

	20.2201(b)		20.2203(a)(2)(v)		50.73(a)(2)(i)		50.73(a)(2)(viii)
	20.2203(a)(1)		20.2203(a)(3)(i)		50.73(a)(2)(ii)		50.73(a)(2)(x)
	20.2203(a)(2)(i)		20.2203(a)(3)(ii)		50.73(a)(2)(iii)		73.71
	20.2203(a)(2)(ii)		20.2203(a)(4)	X	50.73(a)(2)(iv)		OTHER
	20.2203(a)(2)(iii)		50.36(c)(1)		50.73(a)(2)(v)		(Specify in Abstract below or in NRC Form 366A)
	20.2203(a)(2)(iv)		50.36(c)(2)		50.73(a)(2)(vii)		

LICENSEE CONTACT FOR THIS LER (12)

NAME	TELEPHONE NO. (Include Area Code)
GREGORY A. MARET, PLANT MANAGER	802-257-7711

COMPLETE ONE LINE FOR EACH COMPONENT FAILURE DESCRIBED IN THIS REPORT (13)

CAUSE	SYSTEM	COMPONENT	MANUFACTURER	REPORTABLE TO EPIX	CAUSE	SYSTEM	COMPONENT	MANUFACTURER	REPORTABLE TO NPRDS
B	TB	49	G080	YES	NA				
NA					NA				

SUPPLEMENTAL REPORT EXPECTED (14)				EXPECTED SUBMISSION DATE (15)	MO	DAY	YEAR
	YES (If yes, complete EXPECTED SUBMISSION DATE)	X	NO				

ABSTRACT (Limit to 1400 spaces, i.e., approximately 15 single-spaced typewritten lines) (16)

On November 25, 1997 a plant trip occurred at Vermont Yankee. The cause of the trip was the failure of a protective device in the Main Generator protective circuitry. Errors made in the switchyard motor operated disconnect operating sequence, performed in support of transmission grid maintenance activities, resulted in a perturbation in the 345 kV transmission system, which in turn caused an initiation of an automatic reduction in steam admitted to the Main Generator turbine. The ramped power reduction should not have exceeded the approximate 0.1 seconds of the perturbation, resulting in minimal impact upon plant operation. However, a comparator/relay failure in the generator protection circuit prevented the circuit from responding to the resumption of normal comparator inputs, causing the automatic generator load reduction to continue. The operating crew performed the actions prescribed by plant procedures in response to the runback. The adequacy of those procedures are being verified. The automatic reduction in steam to the turbine results in a marked reduction in feedwater heating, and a resulting positive reactivity addition, ultimately leading to a flow-biased scram. The comparator initiated runback has since been removed from the circuit under the VY temporary modification process. Because the conditions which occurred in this event were bounded by the current analysis of record, and the analysis of record demonstrates that all safety design limits for abnormal operational transients were met, this event presented no increased risk to public health or safety.

DESCRIPTION OF EVENT

On November 25, 1997, at 0649 hours, while operating at 85% of rated thermal power, a reactor scram occurred. The plant operating crew and plant equipment responded as intended to bring the plant to a stable shutdown condition. The following describes the sequence of events surrounding the automatic plant shutdown.

Work scheduled for performance on 11/25/97 required that portions of the 345,000 Volt (345kV) transmission grid (EIIS=EA) be isolated. To that end, a Vermont Yankee (VY) Auxiliary Operator (AO) was dispatched to work in coordination with the switchyard control authority to establish the required alignment. Vermont Electric Company (VELCO) is the control authority for the VY station switchyard. When switchyard manipulations are necessary they are performed under the authority of VELCO by VY operations department personnel, in cooperation with the VY control room watch team. The process is controlled by VELCO issuing formal switching orders. These switching orders include step-by-step listings of devices to be positioned, identifying the order of activities and the required position/condition of each affected item.

On the morning of 11/25/97, while the VY operating crew was in the process of slowly raising plant power level after routine control rod manipulations, the on-watch VY Supervisory Control Room Operator (SCRO) received a call from the VELCO Coordinator, requesting that VY support VELCO in the manipulation of various breakers (EIIS=BKR) and electrical disconnects (EIIS=MOD) in the switchyard. A VY AO was assigned the responsibility of supporting the switchyard manipulations.

At 0545, VELCO called the designated VY AO, to begin preparation of the VELCO switching orders. VELCO specified the switching actions to be taken; the AO transcribed these actions onto a VELCO switching order form then implemented the switching order. The last action of each switching order was to report back to VELCO that the required action was complete. Since the switchyard equipment is owned/controlled by VELCO, the VY Control Room is not involved in directing/controlling this activity. Rather, the VY Control Room watch team is periodically updated on the status of the switchyard.

At approximately 0623 hours the VELCO Coordinator directed the AO to perform an additional switching order. The VELCO Coordinator read the required steps to the VY AO (AO No. 1) over the phone. The AO wrote each step down on a VELCO switching order. After having the AO read back the steps recorded on the switching order, the VELCO coordinator directed the AO to perform the prescribed steps. The fourth step of the switching order contained 3 actions for the AO to perform:

1. Verify Motor Operated Disconnect (MOD) number 379-3 OPEN,
2. Decouple the MOD from its motor-positioner, and
3. Lock the MOD in the decoupled position.

The standard approach for opening and closing disconnects for the switchyard MOD's requires that it be performed with its isolation breakers open. MOD 379-3 was opened consistent with this standard practice. Following the opening of MOD 379-3, and prior to its decoupling, its isolation breakers were reclosed for the purpose of maximizing the off-site power grid stability. This was considered the most desirable sequence by VELCO and consistent with the understanding that the fourth step did not involve the repositioning of the MOD, but rather, was limited to separating the disconnect from its motor actuator and locking it in place.

Prior to decoupling the MOD, a second VY AO (AO No. 2) joined AO No. 1 to provide assistance. The design of the MOD being decoupled requires a 180 degree rotation of the manual disconnect/operating lever to fully reposition the 345kV electrical disconnect. To decouple the VY 345kV MOD's requires that a handle be inserted into a sleeve, and that the handle be levered upward. Rotation is not needed for the decoupling. This levering upward of the sleeve and associated linkage was accomplished successfully, and a hinged support foot was rotated into place to retain the driven coupling half (EIIS=CPLG) in the elevated (decoupled) position. The final step of the decoupling process is to lock the driven coupling to the support foot. This step involves aligning a hole drilled in the driven coupling with a hole in the support foot and installing a padlock through

the two holes, effectively locking the MOD in the open position. Aligning the holes to enable the installation of the padlock occasionally requires a slight rotation of the coupling. When AO No. 2 attempted to rotate the coupling, significant resistance to rotation was encountered. As neither of the AO's had in the past performed an MOD decoupling manipulation, it was not clear to either operator if the resistance encountered was unusual. When sufficient force was applied to achieve rotation, the coupling was over rotated an estimated 30 degrees. It should be recognized that the decoupling lever is affixed to the driven end of the coupling and thus remains joined with the electrical disconnect even after the coupling is separated. Thus the rotation of the lever moved the electrical disconnect sufficiently near its associated line to draw an arc between the disconnect and the transmission line, which ultimately resulted in an intermittent phase-to-phase fault. The phase-to-phase fault initiated a generator runback in the turbine runback circuitry due to a mismatch between Main Generator (EIIS=EL) output current and Main Generator Stator Water Cooling flow. As soon as AO No. 2 saw the arc he moved the 379-3 disconnect device back to full open. The AO's then aligned the coupling with the support foot and installed the padlock. Once the 379-3 MOD decoupling device was locked open, the AOs called the Control Room. Neither AO was injured during this event.

Because the heat generated in the Main Generator stator is a function of the stator electric current, the generator manufacturer recommended the installation of a protection feature which continually monitors the operational status of the Stator Water Cooling System (SWCS, EIIS=TJ) to ensure that it was capable of providing adequate cooling to the Main Generator stator. Original plant design was such that an abnormally low pressure or elevated temperature in the SWCS would result in a ramped reduction in steam flow to the Main Turbine Generator. This is achieved by reducing the steam admitted by the Main Turbine Control Valves (MTCV's, EIIS=TA). Additional actions by the turbine Mechanical Hydraulic Control (MHC) system include throttling open the Main Turbine Bypass Valves (MTBV's), maintaining plant pressure constant despite the reduction in steam to the turbine. The ramped steam reduction (termed a turbine runback) results in unloading the Main Generator, reducing the stator current and the corresponding heat load on the SWCS. In 1980 the Main Generator protection circuitry was upgraded by adding the SWCS comparator. The comparator provides protection by comparing SWCS flow to generator output current and initiating a generator runback if a mismatch occurs.

During the 11/25/97 event, a phase-to-phase fault occurred on the 345KV system, which created a transient on the electrical grid. Review of the switchyard oscillograph (EIIS=OSG) confirmed that a high current fault existed for approximately 5 cycles (0.084 seconds). Increased current due to the fault was sensed by the generator current transformers and created a mismatch between Main Generator output current and the flow in the SWCS. Had the system operated as designed its response would have been a turbine runback of approximately 0.1 second duration. This would have had minimal effect upon the plant and would not have resulted in a plant trip.

However, the 11/25/97 turbine runback did not terminate after one tenth of a second. Rather, the turbine load reduction continued to its lower end limit, until a turbine load of less than 29% was achieved. Although the fault in the switchyard cleared in less than 0.1 seconds, the runback continued for 1 minute and 18 seconds and resulted in diversion of steam flow from the Main Turbine to the Main Condenser via the MTBV's (VY has 100% bypass capability). This created a reduction in the steam supplied to the feedwater heating system (supplied from Main Turbine Casing Extraction Steam), which resulted in an increase in reactor core inlet subcooling. The net effect of the increase in core inlet subcooling was an increase in reactor power.

The control room operating crew initiated actions consistent with the plant procedure for a loss of stator water cooling. This procedure includes instructions for the reduction in reactor power by lowering Reactor Water Recirculation flow to 2.6E7 lbm/hr, approximately 54% of rated flow. As a result of the expedited recirculation flow reduction, core flow was reduced to a value slightly below the target value of 54%. Upon recognition that core flow was slightly below the target value of 54%, the licensed control room operator requested, and received permission to raise recirculation flow to restore flow to 2.6E7 lbm/hr. The core power to flow conditions achieved when flow was reduced beneath 2.6E7 lbm/hr was within the core operating region termed the "buffer region." The raising of core flow was considered desirable to ensure that core flow/power instability was precluded. This action was completed per plant operating procedures but a flow-biased trip setpoint was reached at a

FACILITY NAME (1)	DOCKET NUMBER (2)	LER NUMBER (6)			PAGE (3)
		YEAR	SEQUENTIAL NUMBER	REV #	
VERMONT YANKEE NUCLEAR POWER CORPORATION	05000271	97	-- 023 --	00	04 OF 08

TEXT (If more space is required, use additional copies of NRC Form 366A) (17)

reactor power of approximately 85%, before the next phase of power reduction via the manual insertion of control rods could be initiated. It was the transient created by the extended turbine runback which led to the reactor scram 3 minutes and 8 seconds after the runback terminated. The appropriateness of the prescribed and permitted operator actions is currently under evaluation in light of the conditions and responses observed during this transient. Of specific interest is the current practice of allowing and instructing the operating crew to raise flow to exit the buffer region under conditions of an elevated core inlet subcooling. Preliminary analysis shows that the plant may not have reached a flow biased scram setpoint if the crew had not raised core flow to exit the buffer region. Operation within the buffer region is permitted provided that the core stability monitoring equipment is functioning. This equipment was operational during the 11/25/97 event.

System analysis and troubleshooting efforts have concluded that the continued runback was caused by a non-repeatable failure of the current/flow comparator in the Main Generator protection circuitry. This equipment failure could have resulted in a plant trip from a variety of initiators. A grid voltage transient, a stator water cooling flow or flow indication perturbation, and many other postulated scenarios, each of which the plant was designed to accept without an automatic shutdown, could have led to this event.

Equipment History

A review of the current-to-flow comparator history identified that this device was not part of the generator's original design. The device was installed in 1980 to address certain cooling water system failures which could go undetected by both the low pressure and high temperature sensors. In a letter (TIL-881), General Electric (GE) recommended installation of a current-to-flow comparator for use in variable flow systems (such as VY) and also stated that this device, along with pressure and temperature sensors, would protect the generator during any foreseeable event.

As part of the historical review, interviews were conducted with Maintenance Electrical and Controls (Maint/E&C) technicians who have maintained this system during the past 17 years. These individuals identified that except for 1994, VY hasn't experienced any problems associated with this circuit. The failure mode discovered in the 1994 event was examined and it was determined that the symptoms of the 11/25/97 event are indicative of a different failure within the device.

In 1996 GE evaluated VY's Main Generator system and recommended certain improvements be made during the next outage. During GE's evaluation, they determined that the Stator Water Cooling System current flow comparator could be eliminated if the stator cooling system was converted to a constant flow system. Disposition of the recommendations have been assigned to the VY Maintenance Department. No actions have been taken to date, pending receipt of more information from GE.

Recent Troubleshooting Efforts

Subsequent to the 11/25/97 event, testing of each stage of the current-to-flow comparator was performed. This was extended to full functional testing to simulate high current versus normal stator cooling flow. The functional test actuated the runback circuitry to verify it provided the appropriate output. All components in the circuitry performed as designed and the failure could not be repeated. In addition, the functional test was re-performed with the high current signal applied and subsequently removed after 30 seconds. As soon as the high current test signal was removed, the runback initiation signal reset. Additionally, a calibration check of the overcurrent relay was performed and its values were found within tolerance.

During evaluation of the current-to-flow comparator circuit, it was identified that the current-to-flow comparator design inappropriately employs a relay with contacts rated for 28VDC in a 125VDC circuit to provide power to four relays. Upon receipt of a 15% current-to-flow mismatch, the 28VDC rated contact would have closed, energizing four 125VDC relays and initiating the runback. When the 15% condition cleared, the 28VDC contact opened, yet due to the voltage transient generated by de-energizing the four relays, the contact break arc may have been sustained, causing the runback to continue.

In addition to identifying that relay contacts were not used in a proper application, VY identified that failure of the power supply to the current-to-flow comparator would also result in a runback to its limit. The power supply to the current-to-flow comparator is Instrument 120VAC. Plant process computer data points on the Instrument 120VAC line that feeds the current-to-flow comparator were reviewed. This data showed no indication that power had been lost to the current-to-flow comparator. The process computer also indicates that the SWCS pressure and temperature were also normal at the time of the runback. Therefore, there is a high degree of confidence that the runback was not due to a loss of the 120VAC instrument power supply or a SWCS failure, but rather to the failure of the comparator itself.

Turbine Runback Conclusions

While the exact cause for continuance of the runback signal from the comparator could not be determined, VY did identify that the current-to-flow comparator was of a poor design and detrimental to plant reliability. As stated earlier in this report, the purpose of the current-to-flow comparator was to protect the stator windings during a loss of stator cooling water. Although the circuit would protect the stator windings, it was identified during the cause investigation that a loss of the single power supply to the current-to-flow comparator would have resulted in a positive reactivity insertion transient, and potentially a reactor scram.

Based upon the findings during troubleshooting and cause investigation, VY determined that the automatic runback portion of the current-to-flow comparator should be disabled. This decision was based upon:

* the design flaws discussed above
* this component was not part of the original generator design
* GE recommendation that this design should be replaced with a more reliable device
* this design was originally intended for a variable flow system and VY's system is operated as a fixed flow system
* other plants (non-nuclear) have experienced problems with comparator relay contacts sticking
* the VY SWCS has proven very reliable
* the generator protection system will continue to provide protection by the temperature and pressure functions

A 10CFR50.59 safety evaluation was performed for a Temporary Modification to disconnect the automatic runback portion of the current-to-flow comparator. The current-to-flow comparator is still installed but provides only an alarm function. Upon receipt of this alarm, operators will have the ability to manually initiate a runback, if appropriate.

CAUSES OF EVENT

This event was initiated by an operator action which revealed opportunity for improvements in the VY staff's understanding of the implications of the coupling and decoupling activities involving energized disconnects. It also demonstrated that the process used in the control of devices in the VY switchyard warranted enhancement. However, the root cause of the event was the failure of plant equipment.

Investigation on issues relative to this event continues. The final issue to be addressed is appropriateness the procedural guidance currently provided to the operating crews for response to the turbine runback. If the results of that evaluation conclude that the instructions provided to the operating crews need to be revised a supplement to this report will be issued. The following causes and corrective actions assume that the procedural guidance currently provided to the operating crews is appropriate.

Root Cause

1. Although the exact failure mechanism of the current-to-flow comparator is not known, the cause for the continuation of the runback, and thereby the scram, is a failure of the current-to-flow comparator

Contributing Causes

1. A contributing cause to this event is a poor design, in that the vendor installed a control relay rated for 28VDC in a 125VDC application. This design may have resulted in a sustained arc across the 15% relay contacts.

2. Another contributing cause was the lack in the managerial methods employed. Specifically the responsibility of the Control Room Shift Supervisor was inadequately defined with respect to oversight of switchyard activities. Excess emphasis was placed on VELCO's authority, which resulted in a missed opportunity to re-evaluate the evolution when decoupling difficulty was encountered.

3. A third contributing cause was a lack of knowledge/understanding on the part of the plant operating staff relative to the potential risks involved in the coupling/decoupling of open motor operated disconnects near energized conductors.

ANALYSIS OF EVENT

The event reported herein is similar to the loss of stator water cooling transient analyzed and described in the VY Final Safety Analysis Report (FSAR). Although the cooling to the Main Generator Stator was never actually in jeopardy, the Main Generator protection circuitry initiated actions consistent with a sustained loss of stator water cooling. The VY FSAR provides the following assessment of the limiting loss of stator water cooling transient:

> "In response to a loss of stator cooling, a turbine runback is initiated to reduce generator output to less than 29% of rated output. This runback is accomplished by bypassing main steam from the turbine directly to the main condenser. Since heating steam to the feedwater heaters is supplied from the turbine stages, the amount of steam available for feedwater heating is significantly reduced. The reduction of heating steam to the feedwater heaters results in a severe subcooling event.
>
> For the analysis, the loss of stator cooling event is initiated at, or near, rated thermal power (maximum 104.5%). It is assumed that an instantaneous loss of extraction steam occurs to the No. 1-4 feedwater heaters of both feedwater trains. This is a conservative assumption, since there would not be a total loss of steam to the feedwater heaters, and the reduction in heating steam would occur over the several minutes required for the turbine runback. Also, no credit is taken for the heat capacity of structural materials in the process piping or feedwater heaters. This results in a [stepwise] decrease in feedwater inlet temperature as the feedwater travels through the feedwater piping to the reactor vessel.
>
> The decrease in feedwater temperature results in a subsequent reduction in core inlet temperature. Due to the negative void coefficient, core thermal power increases. The transient is terminated by APRM high flux trip at 120% of rated core thermal power.
>
> The resulting thermal limits for this event are comparable to the loss of a feedwater heater and the inadvertent HPCI pump start events."

SAFETY SIGNIFICANCE

Because the conditions which occurred in this event were bounded by the current analysis of record, and the analysis of record demonstrates that all safety design limits for abnormal operational transients were met, this event presented no increased risk to public health or safety.

CORRECTIVE ACTIONS

Immediate Actions:

1. The operating staff placed the plant in a normal shutdown configuration.

2. An inspection of the affected MOD was performed to determine if the arc had caused any equipment damage. The inspection revealed no equipment damage.

3. Craft and engineering personnel performed troubleshooting of the affected Main Generator protection circuitry.

4. A temporary modification was implemented to remove the current-to-flow comparator from the Main Generator protection circuitry. The comparator will continue to provide output for the alarm function.

5. A post trip investigation was performed by the plant Operations Department.

6. Shift training was conducted on this event, and the particulars of the event included in the Operations Department Night Orders.

7. Agreements were reached with VELCO for the VY Control Room to obtain advance copies of VELCO tagouts, for non-emergency evolutions, for review and concurrence.

Long Term Actions:

1. VY will evaluate alternative designs to be applied in lieu of the current-to-flow comparator. The expected completion date is 07/30/98.

2. VY will inspect the current-to-flow comparator following its replacement by the selected configuration change to determine the failure mechanism, if possible. The expected completion date is 08/30/98.

3. VY will conduct Auxiliary Operator refresher training on MOD decoupling. The training will include a discussion on the potential impact of operating disconnects when one side of the disconnect is energized. VY will also ensure that AO initial training includes this issue. The expected completion date is 07/30/98.

4. VY will evaluate the removal of the turbine runback circuitry, for replacement with a more appropriate protective feature. The expected completion date is 05/01/98.

5. VY will Meet with VELCO to discuss the need to continue the practice of decoupling. The expected completion date is 02/01/98.

6. Develop an Operating Standard on Switchyard Operations that defines VY Management's expectations for the level of oversight and authority the VY Shift Supervisor is expected to have over switch yard activities. The expected completion date is 02/15/98.

ADDITIONAL INFORMATION

Vermont Yankee considers the following events, reported within the past five years, to be similar in that each involves a plant trip either due to an equipment problem, or involving human error.

VY LER	Date	Title
95-21	12/08/95	Plant scram due to turbine trip resulting from high reactor water level caused by feedwater regulating valve failure (material problem).
96-19	08/27/96	Half scram and Group III containment isolation caused by loose Rx Protection System breaker (material problem).
97-08	04/24/97	Plant Scram Due to Procedural Non-compliance and Failure to Perform Self Verification During Nuclear Instrumentation Calibration (involved human error).